Modelling the surface energy balance characteristics of two contrasting urban settings with the Community Land Model Urban (CLMU)

Matthias Demuzere, K. Oleson, A. Coutts, G. Pigeon, N.P.M van Lipzig

Research questions

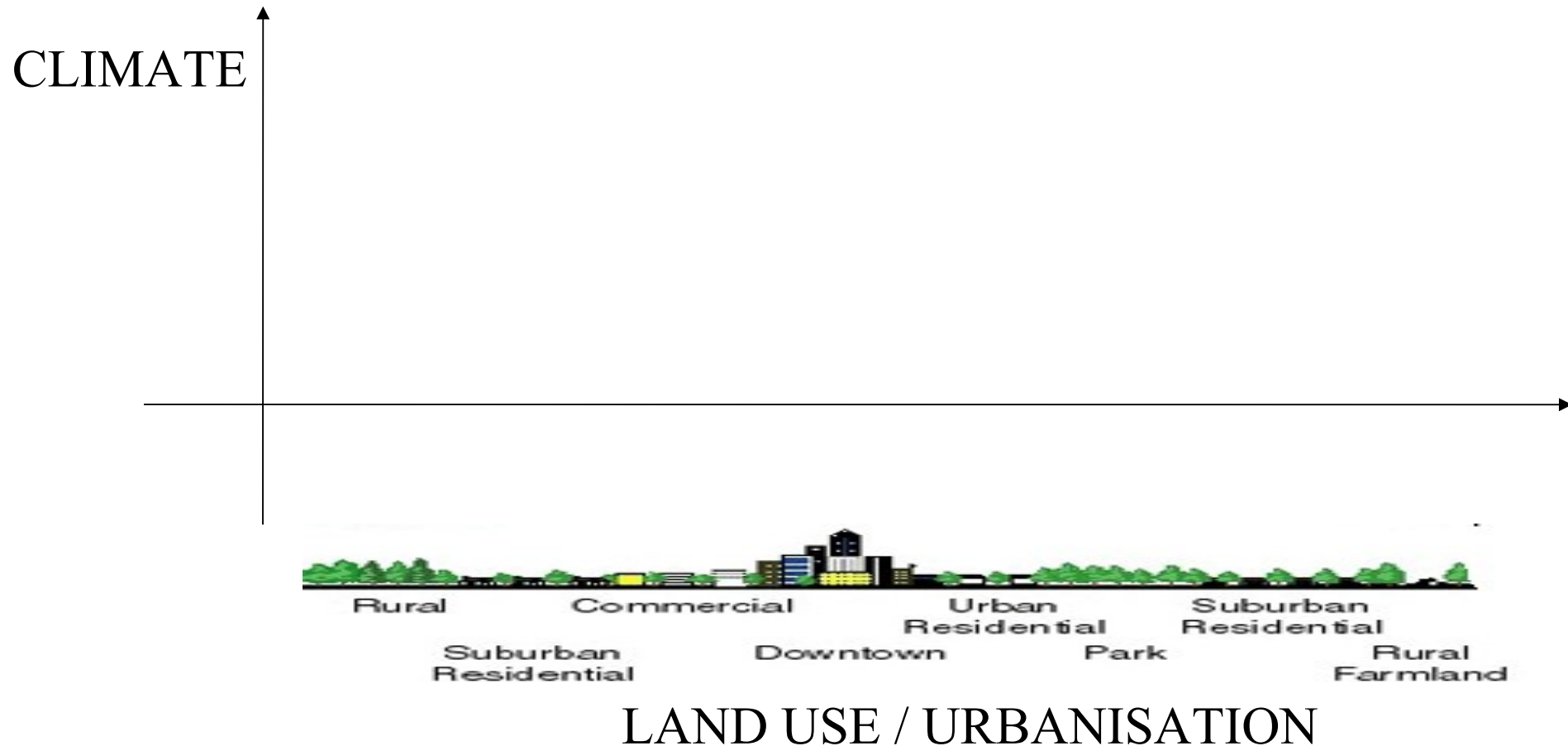CLIMATE $\longleftrightarrow$ LAND USE / URBANISATION

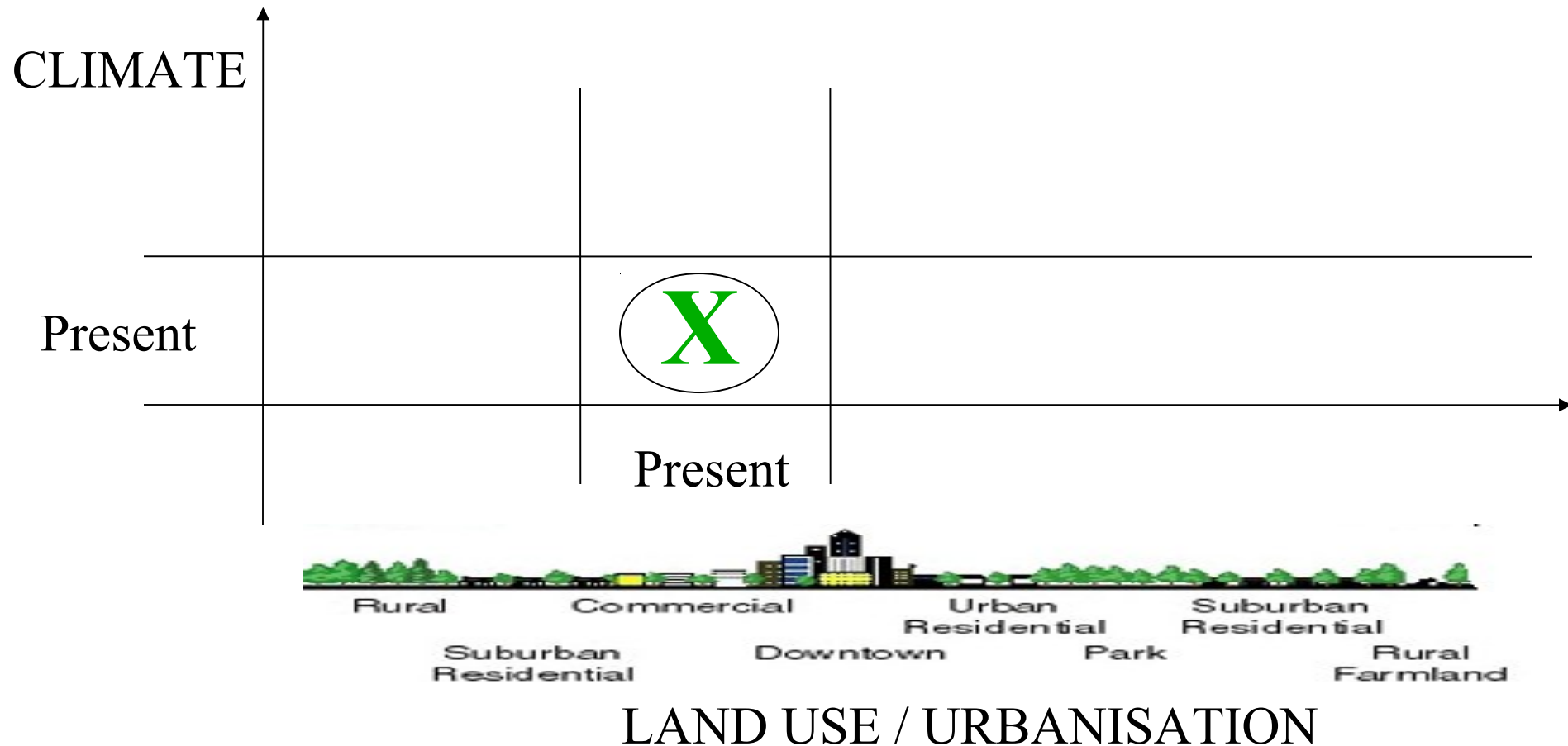In a high-resolution regional climate context

Spatial scales: 10-3 km
Main cities of interest: Melbourne & Toulouse
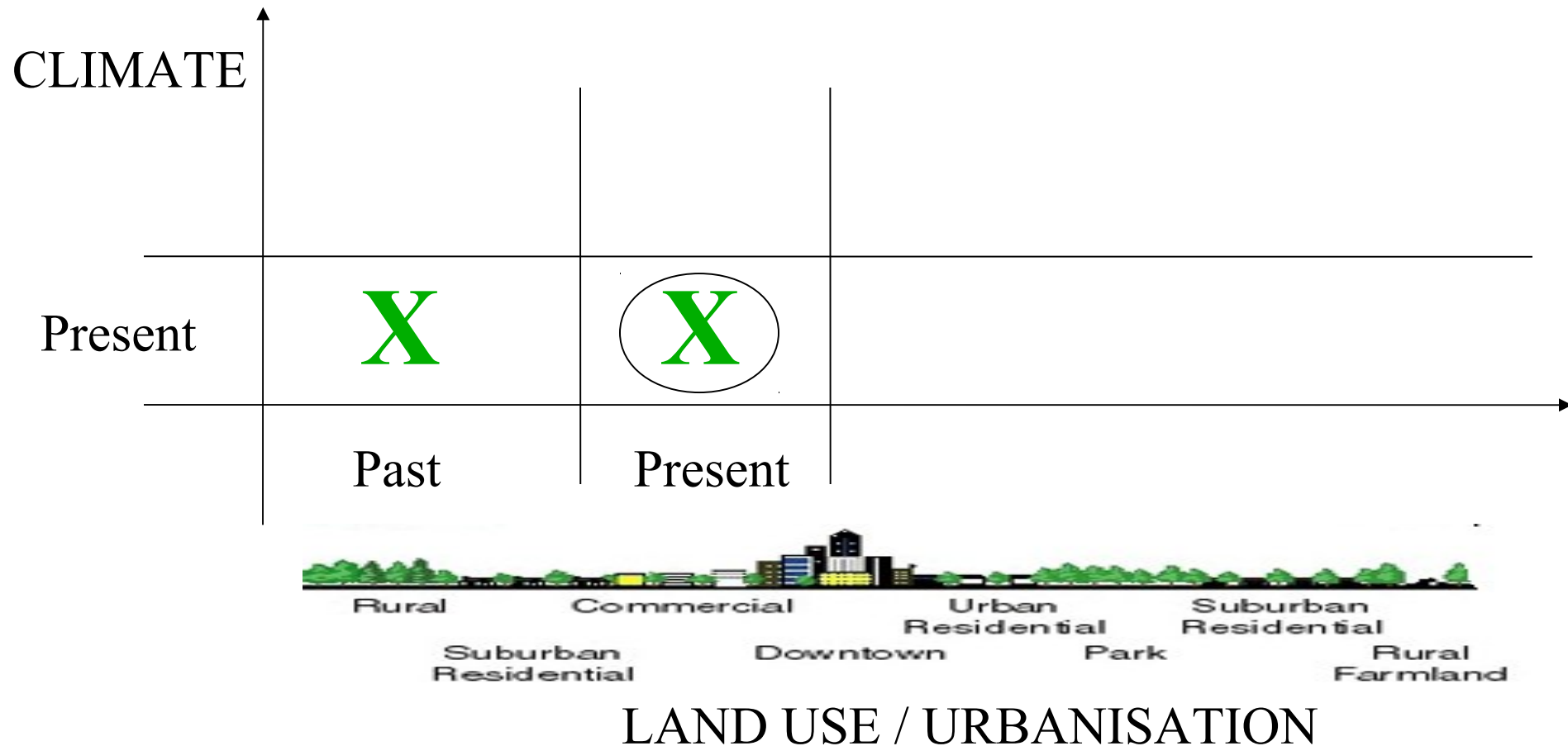Temporal: diurnal cycle, hourly, day - night

Research questions

CLIMATE

Rural   Commercial   Urban
                       Residential   Suburban
                                      Residential

Suburban   Downtown   Park   Rural
Residential   Farmland

LAND USE / URBANISATION

Research questions

CLIMATE

Present

X

Present

Rural   Commercial   Urban Residential   Suburban Residential

Suburban Residential   Downtown   Park   Rural Farmland
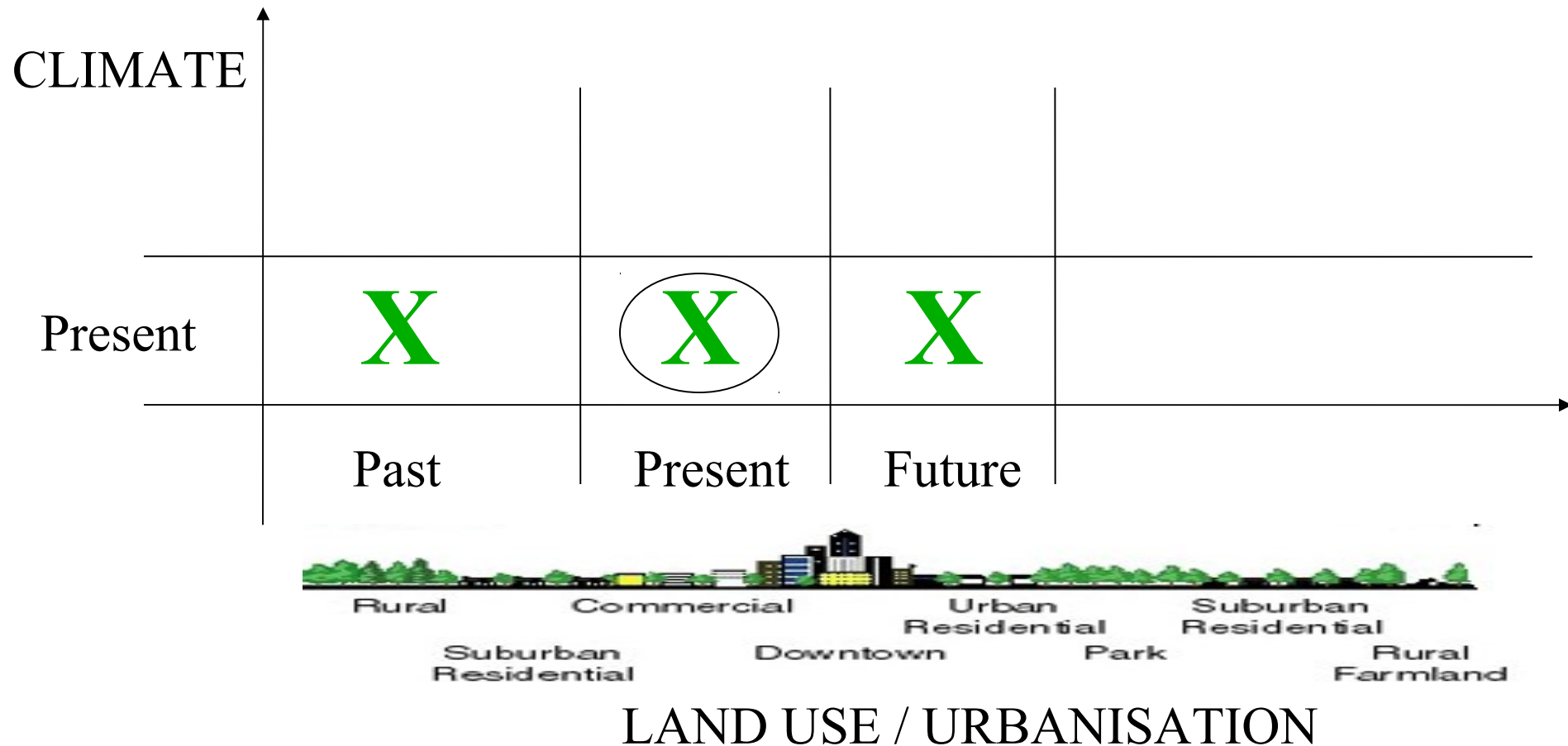
LAND USE / URBANISATION
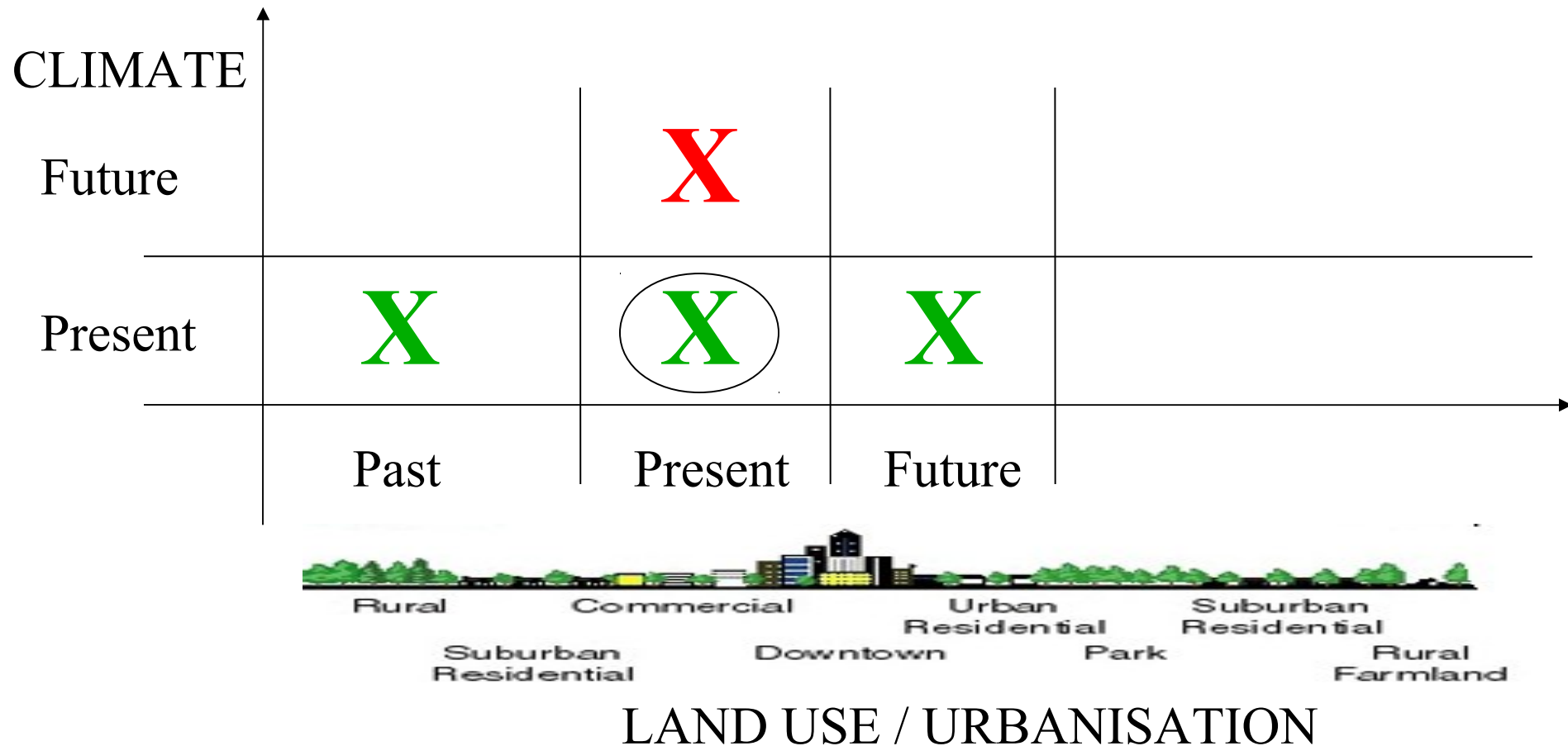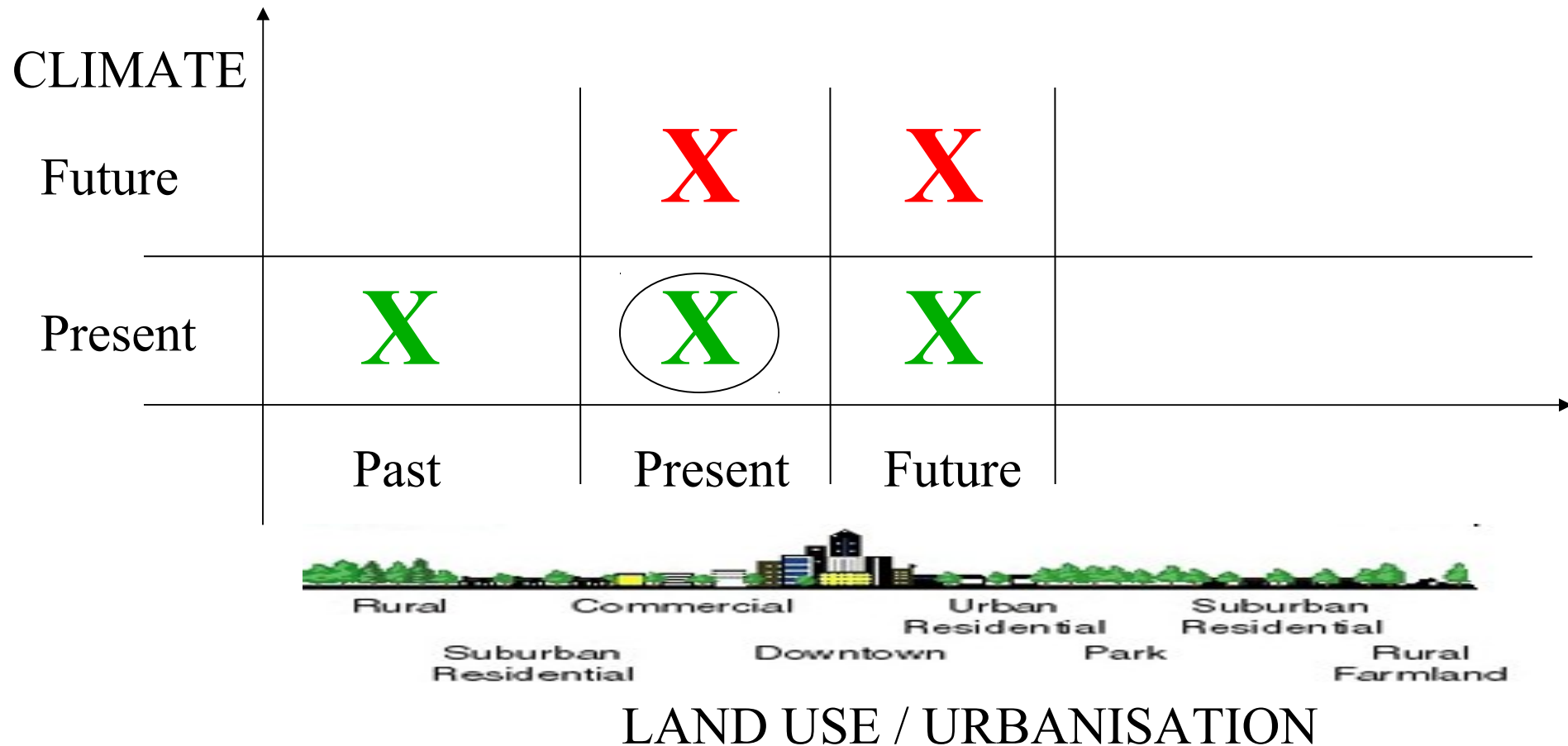
Research questions

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A. What is the effect of the historic, present-day and future land use on the present-day climate

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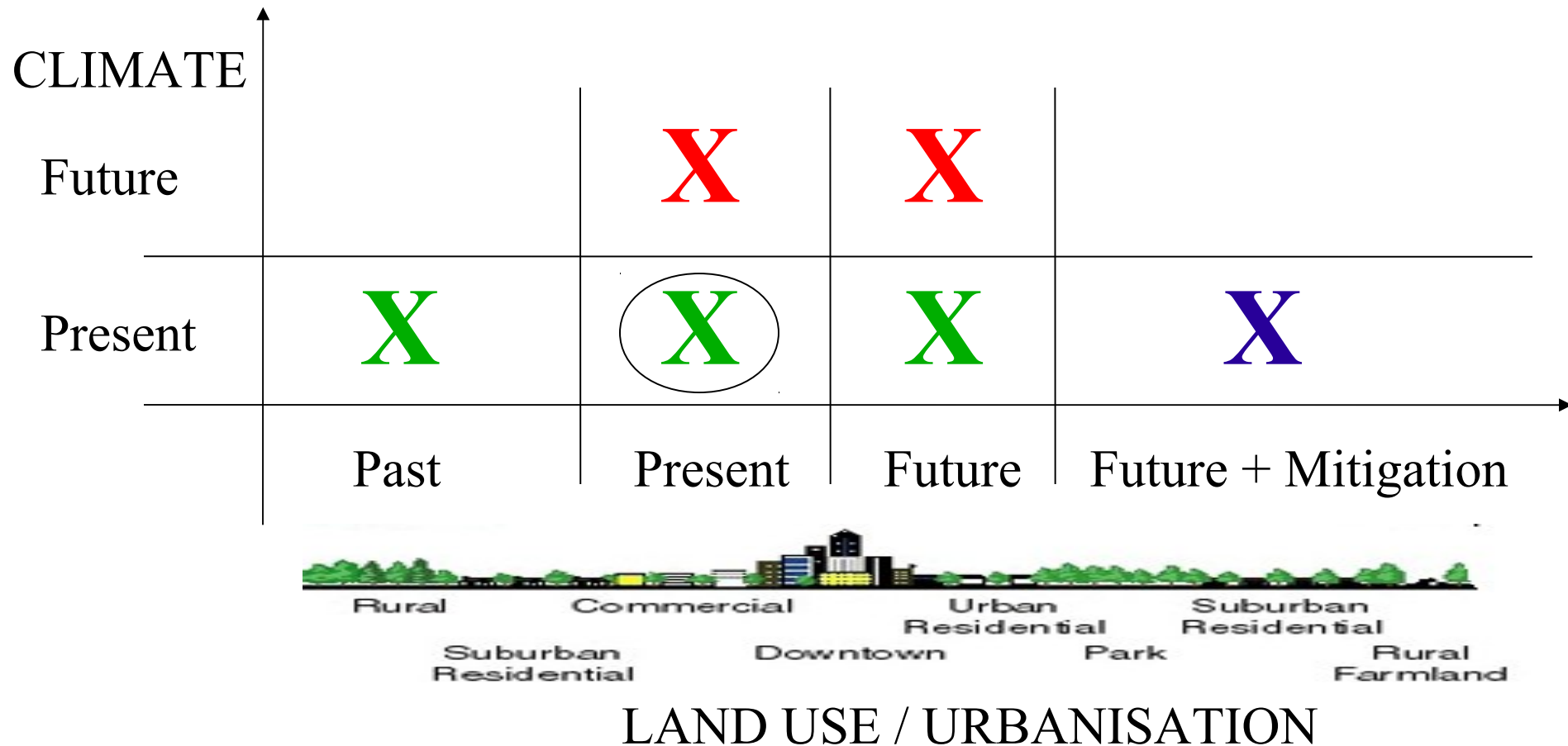

CLIMATE

Future   **X**

Present   **X**   **X**   **X**

     Past   Present   Future

Rural   Commercial   Urban   Suburban
                 Residential   Residential

Suburban   Downtown   Park   Rural
Residential   Farmland

LAND USE / URBANISATION

Research questions

A. What is the effect of the historic, present-day and future land use on the present-day climate
B. What is the additional effect of a changing climate??

CLIMATE

Future   **X**   **X**

Present   **X**   **X**   **X**

Past   Present   Future

Rural   Commercial   Urban Residential   Suburban Residential

Suburban Residential   Downtown   Park   Rural Farmland
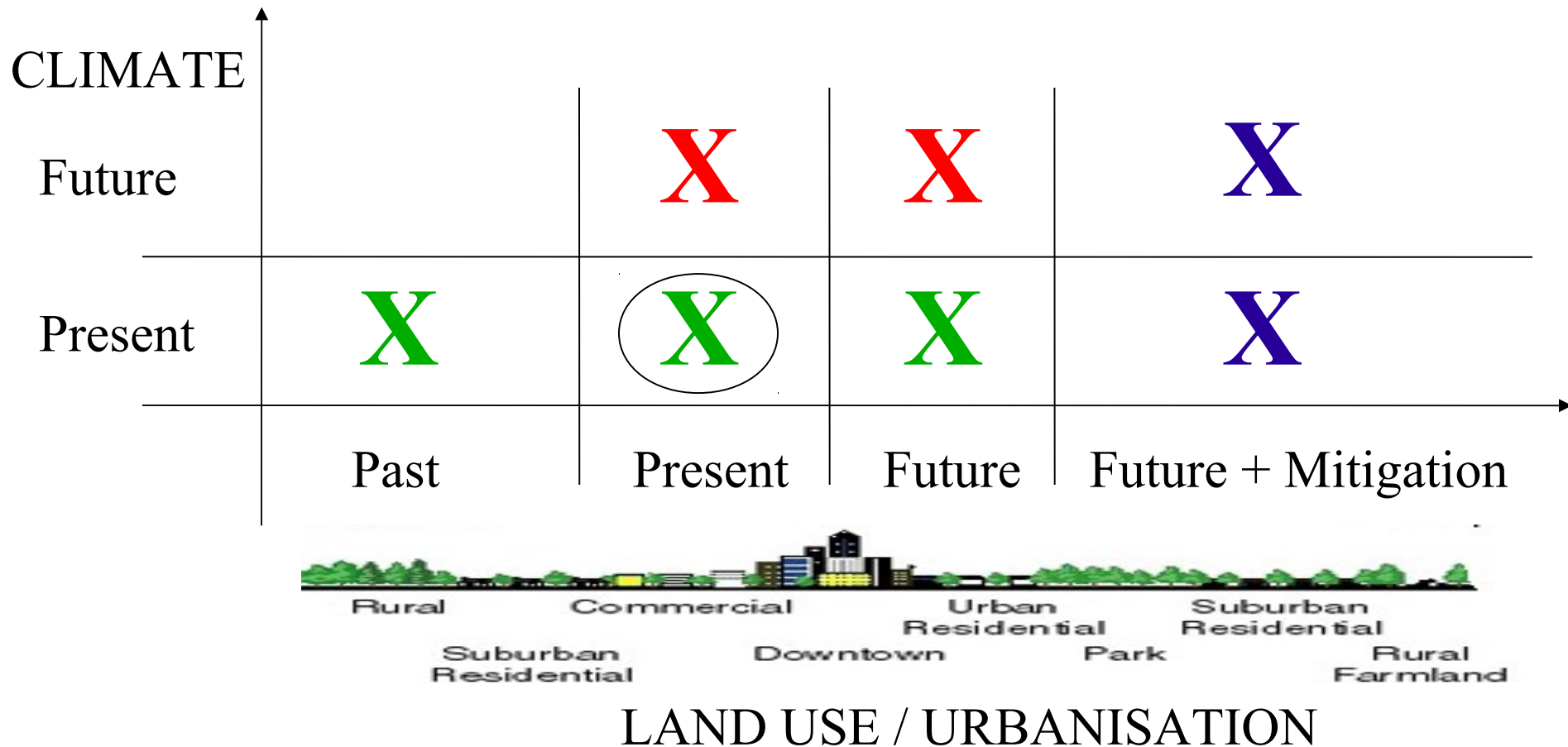
LAND USE / URBANISATION

Research questions

A. What is the effect of the historic, present-day and future land use on the present-day climate
B. What is the additional effect of a changing climate??

CLIMATE

Future

Present

Past   Present   Future   Future + Mitigation

LAND USE / URBANISATION

Research questions

A. What is the effect of the historic, present-day and future land use on the present-day climate

B. What is the additional effect of a changing climate??

C. To what extent can these impacts be mitigated by WSUD or other thermal, radiative or geometric-related mitigation strategies?
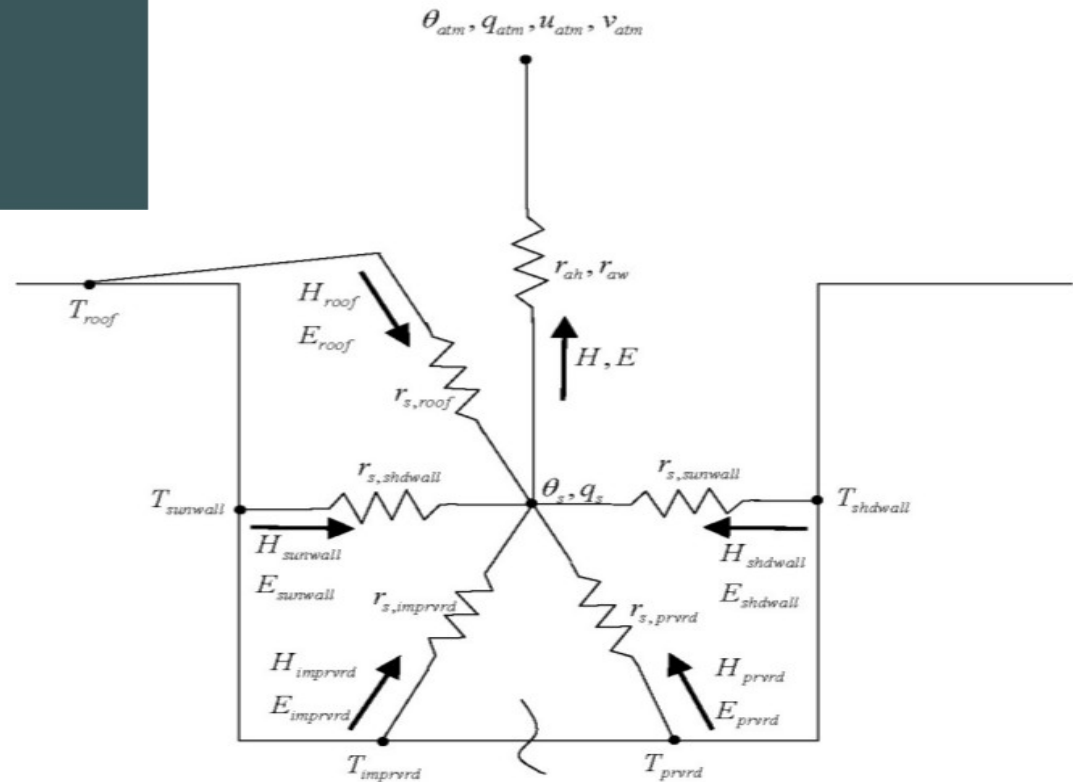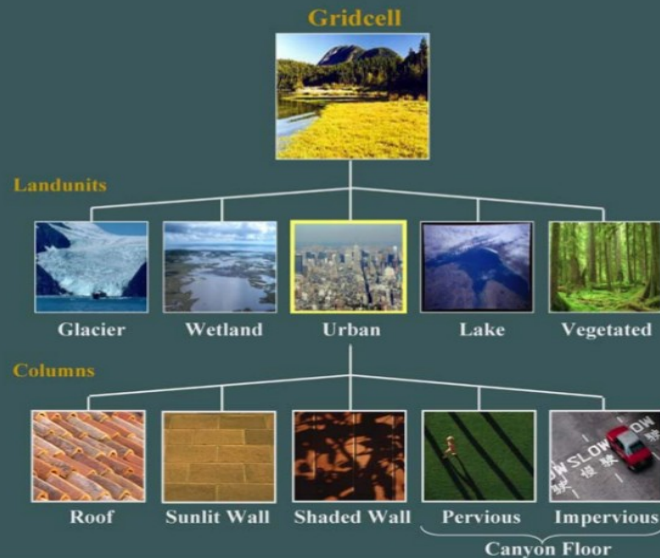

LAND USE / URBANISATION

Modelling approach

U, T, q, P, S↓, L↓ (atm)

COSMO-CLM

Z'$_{atm}$

Clm 4.0

H

H, E, L , I↑, S↑, T, q, u, τ (urban canopy

COSMO4.8-CLM11-OASIS3-Clm4.0

Modelling approach

Offline evaluation strategy

▪ Model is used with OBSERVED atmospheric forcing (incoming short- and longwave radiation, pressure, temperature, wind speed and humidity from Toulouse and Melbourne

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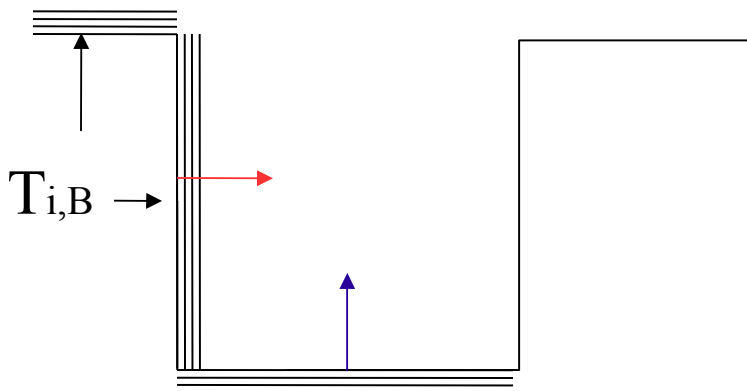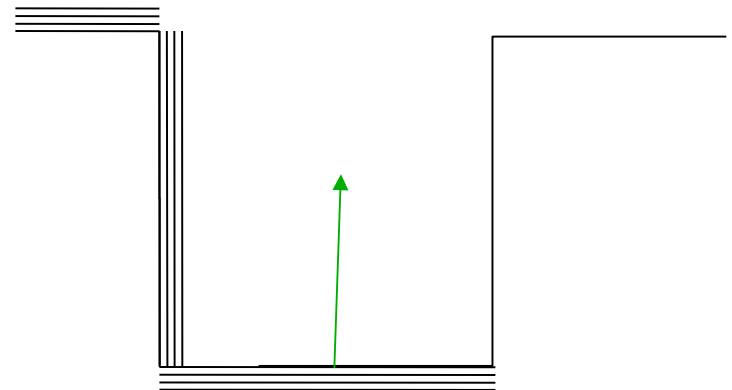

Toulouse, France

Preston (Melbourne), Australia

Offline evaluation strategy

▪ Model is used with OBSERVED atmospheric forcing (incoming short- and longwave radiation, pressure, temperature, wind speed and humidity from Toulouse and Melbourne
▪ Urban properties are derived from observations (literature)
▪ Anthropogenic heat is taken into account

$Q_{f,traffic}$ prescribed
$Q_{f,heating}$ calculated

Total Q_f is precribed


$T_{i,B}$ →

Toulouse

Melbourne

Offline evaluation strategy

▪ Model is used with OBSERVED atmospheric forcing (incoming short- and longwave radiation, pressure, temperature, wind speed and humidity from Toulouse and Melbourne

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▪ Model is run for 1 point in 2 different ways: URB and URB_VEG
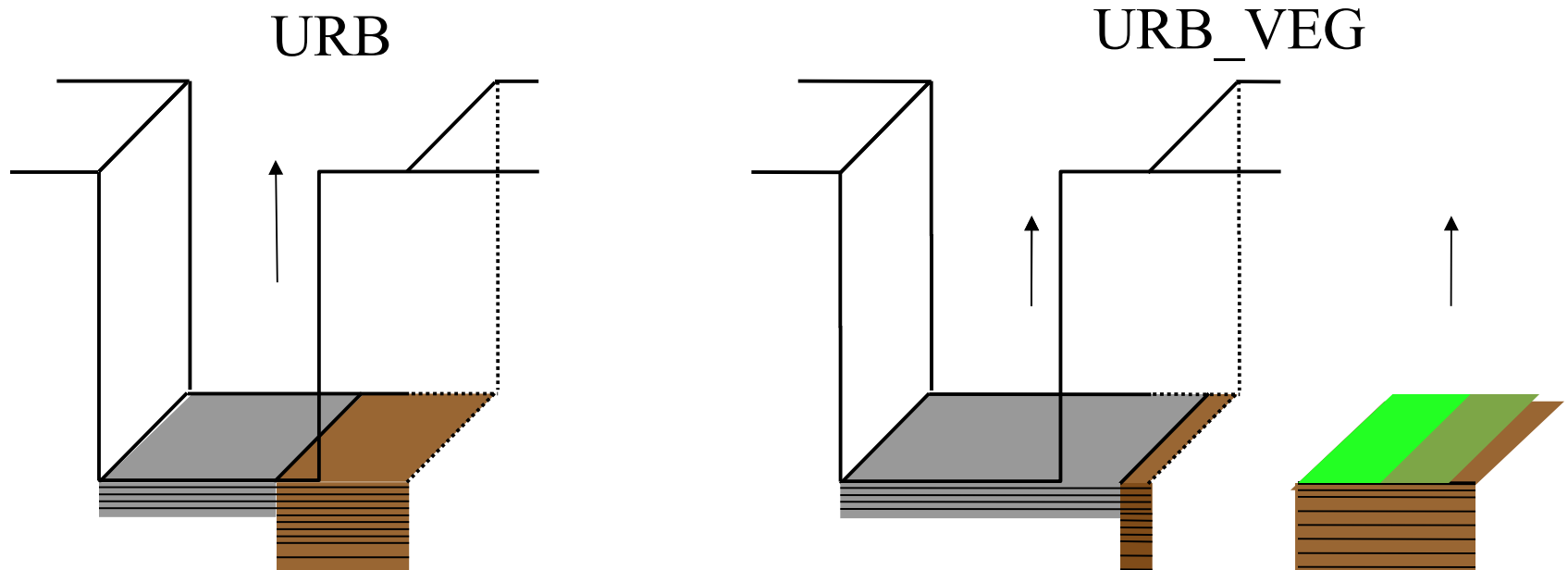
URB   URB_VEG
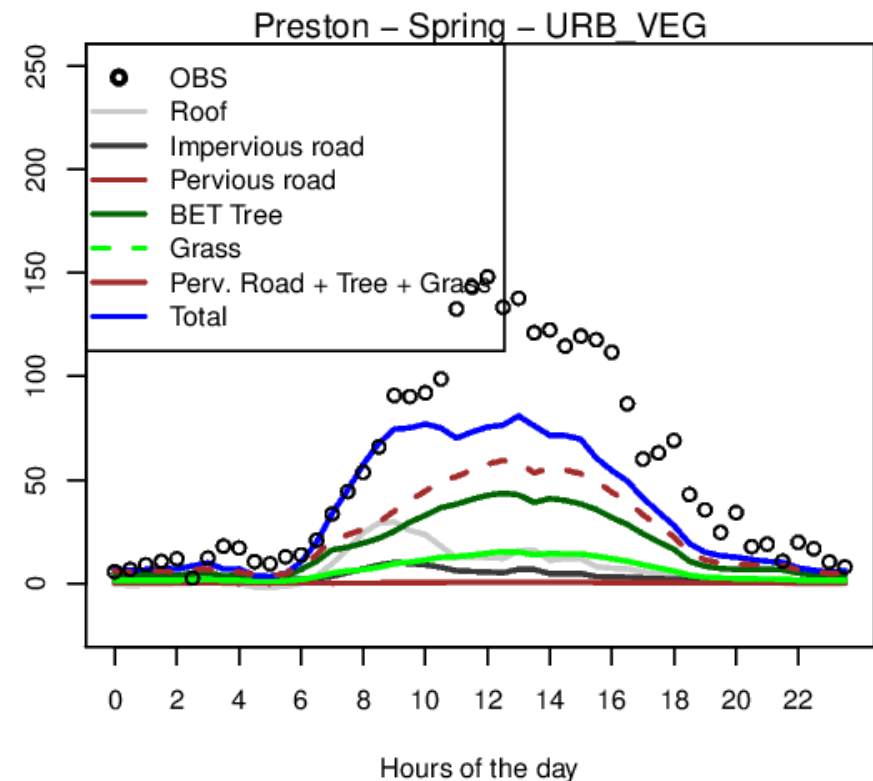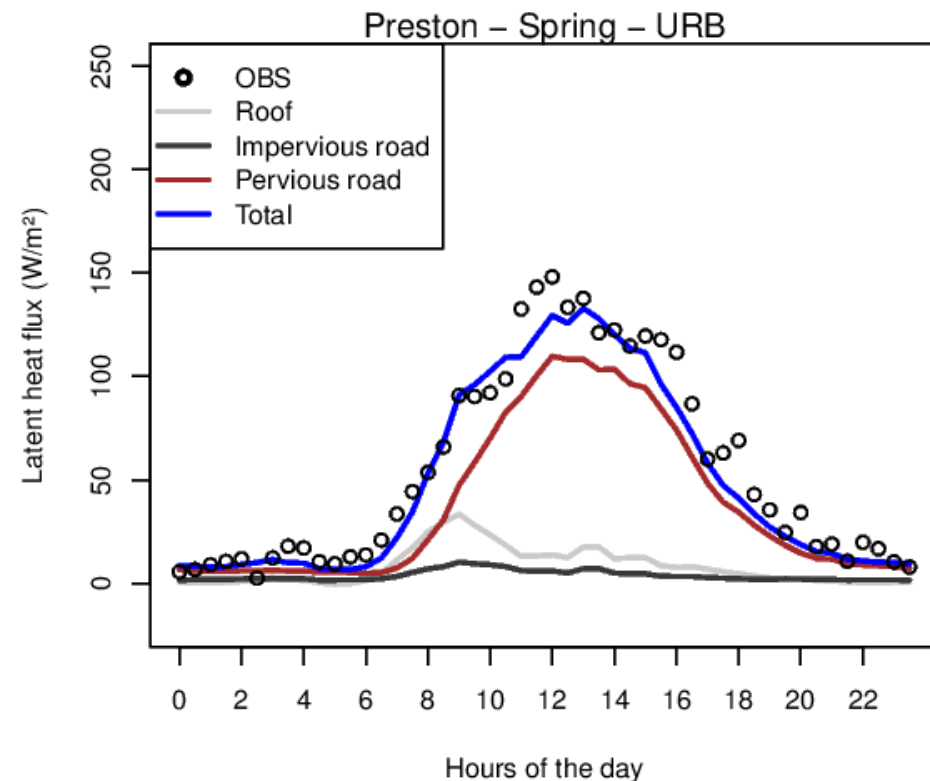
Results for Melbourne, eg. Preston
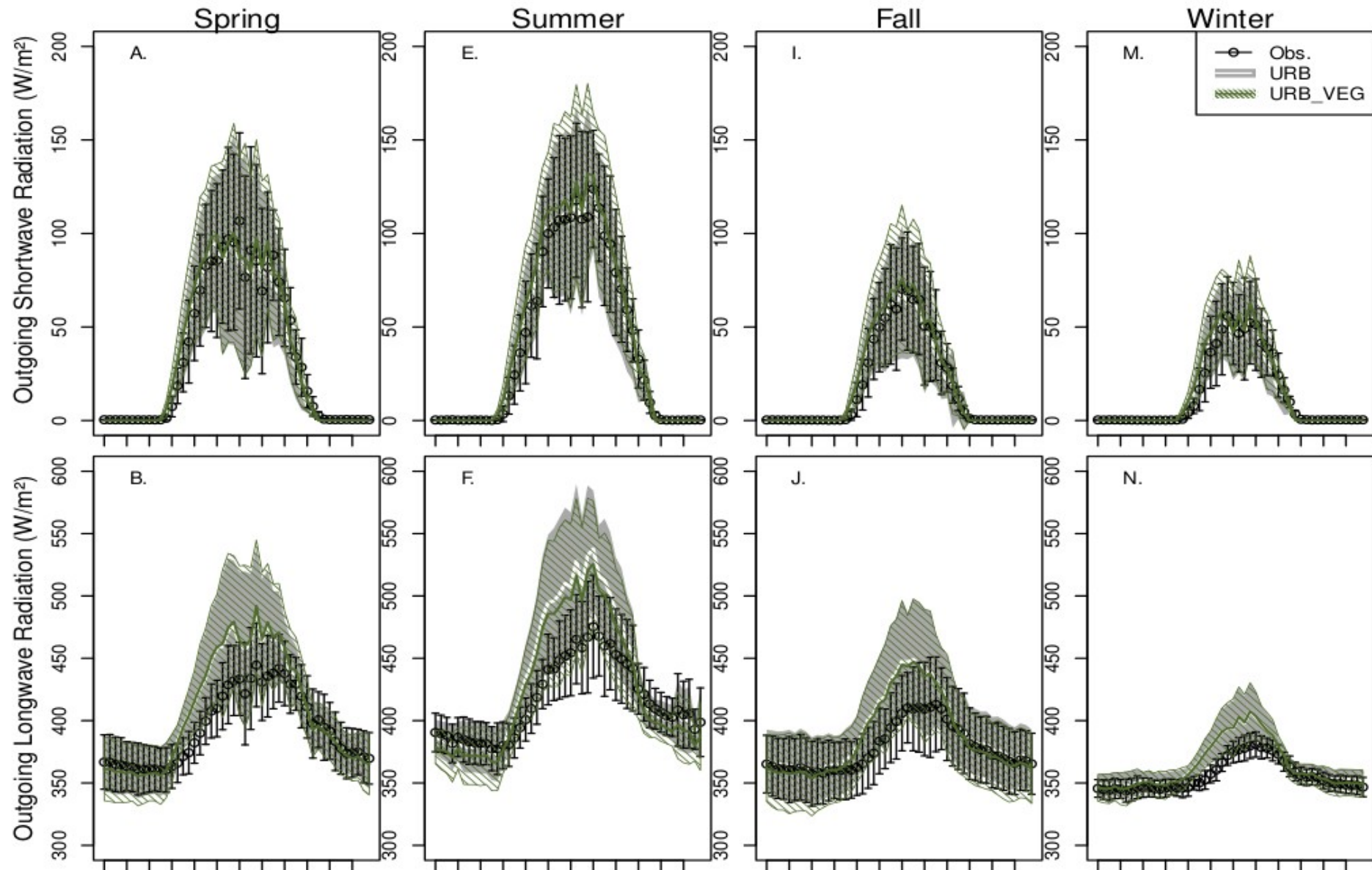
Results for Melbourne, eg. Preston
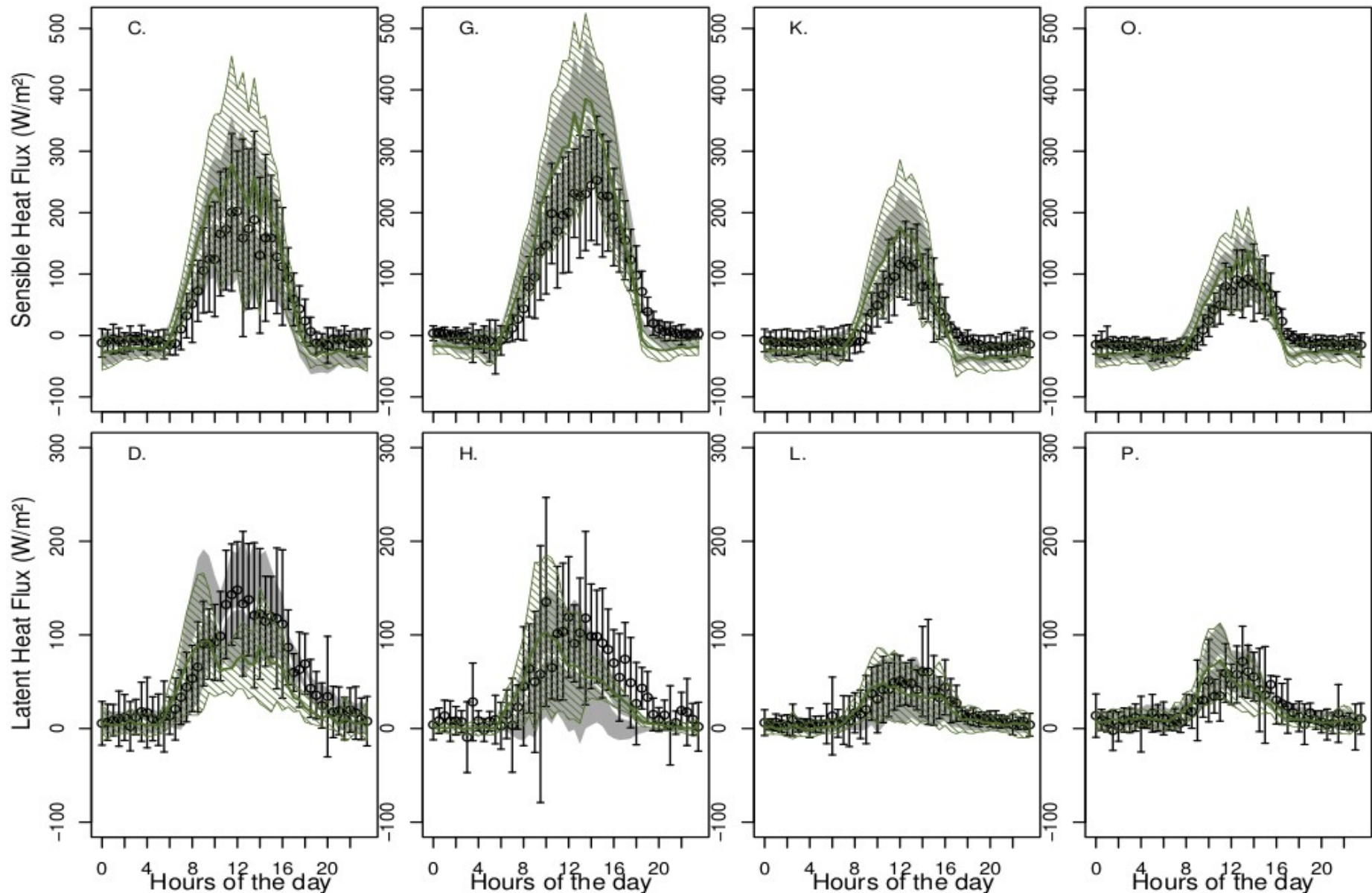
Results for Melbourne, eg. Preston

- Similar results are obtained for Armadale and Surrey Hills
- As Preston is characterized by a relatively large amount of vegetation, it is possible to have a look at the sources of Qe

Sensitivity to Eucalypt

	Default	Eucalypt-specific
$z_{0m,v}$	1.2	2.41
$r_{s,min}$	-	250
$z_{top,BET}$	35	16 (12)
$z_{top,BDT}$	20	16 (12)
$LAI_{max,BET}$	2.6	3.2
α_{vis}^{leaf}	0.1	0.44
α_{nir}^{leaf}	0.45	0.6
τ_{vis}^{leaf}	0.05	0.03
τ_{nir}^{leaf}	0.25	0.36
χ_L	0.1	-0.38

$\longrightarrow$

	Preston			
	K↑	L↑	Qh	Qe
Winter				
ΔMBE	3.6	0.1	4.8*	1.3*
ΔRMSE	6.1	**-0.4**	**-2.3**	0.3
Spring				
ΔMBE	6.7	0.0	**-7.9***	**-1.3**
ΔRMSE	10.3	**-0.8**	**-7.5**	**-0.1**
Summer				
ΔMBE	10.0	**-0.5**	**-9.0**	0.1
ΔRMSE	13.7	**-0.8**	**-9.2**	0.5
Fall				
ΔMBE	3.7	0.5	2.4*	**-0.5**
ΔRMSE	6.8	**-0.5**	**-2.4**	0.5

Bold: Improvement compared to dafult URB_VEG run
*: changes larger than the uncertainty of the turbulent fluxes

Other elements that effect Qe

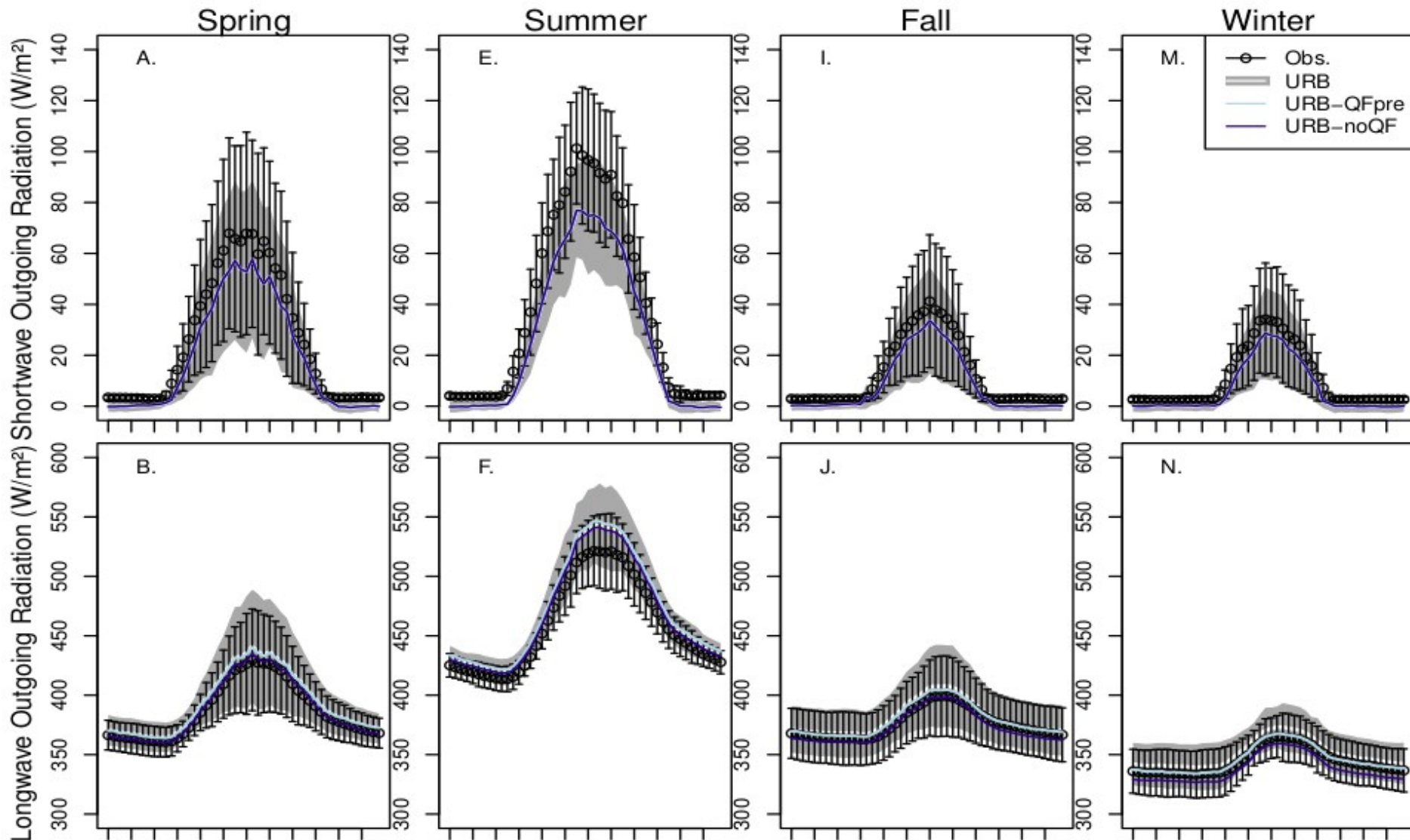Soil texture defined as sandy loam:
- Sand: 50 – 80%
- Clay: 0 – 20%

Amount of water that can be stored on the impervious surface
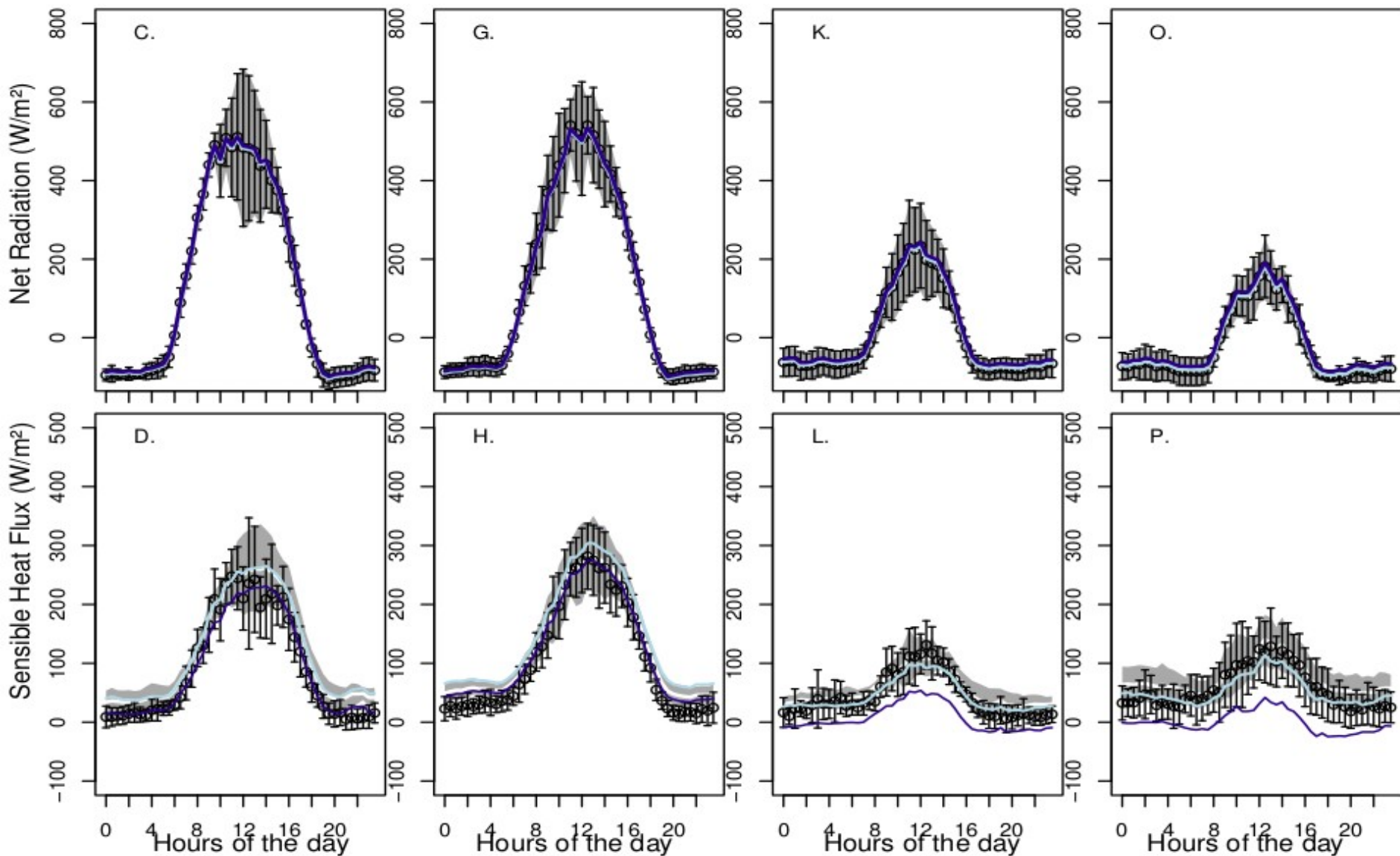- Default: 1 mm
- Test with + and – 50%

|Qe_experiment| - |Qe_URB| for Armadale in summer

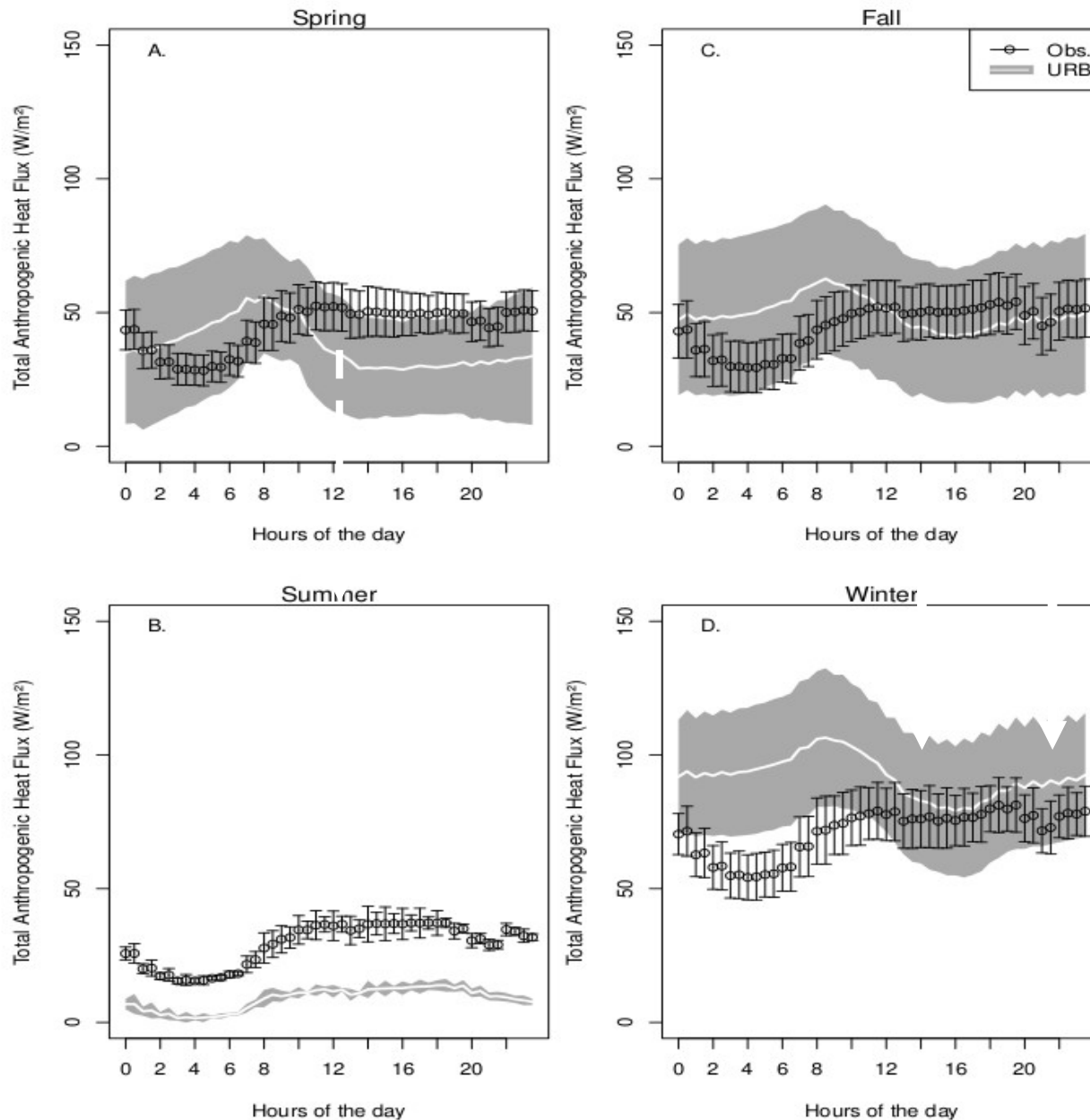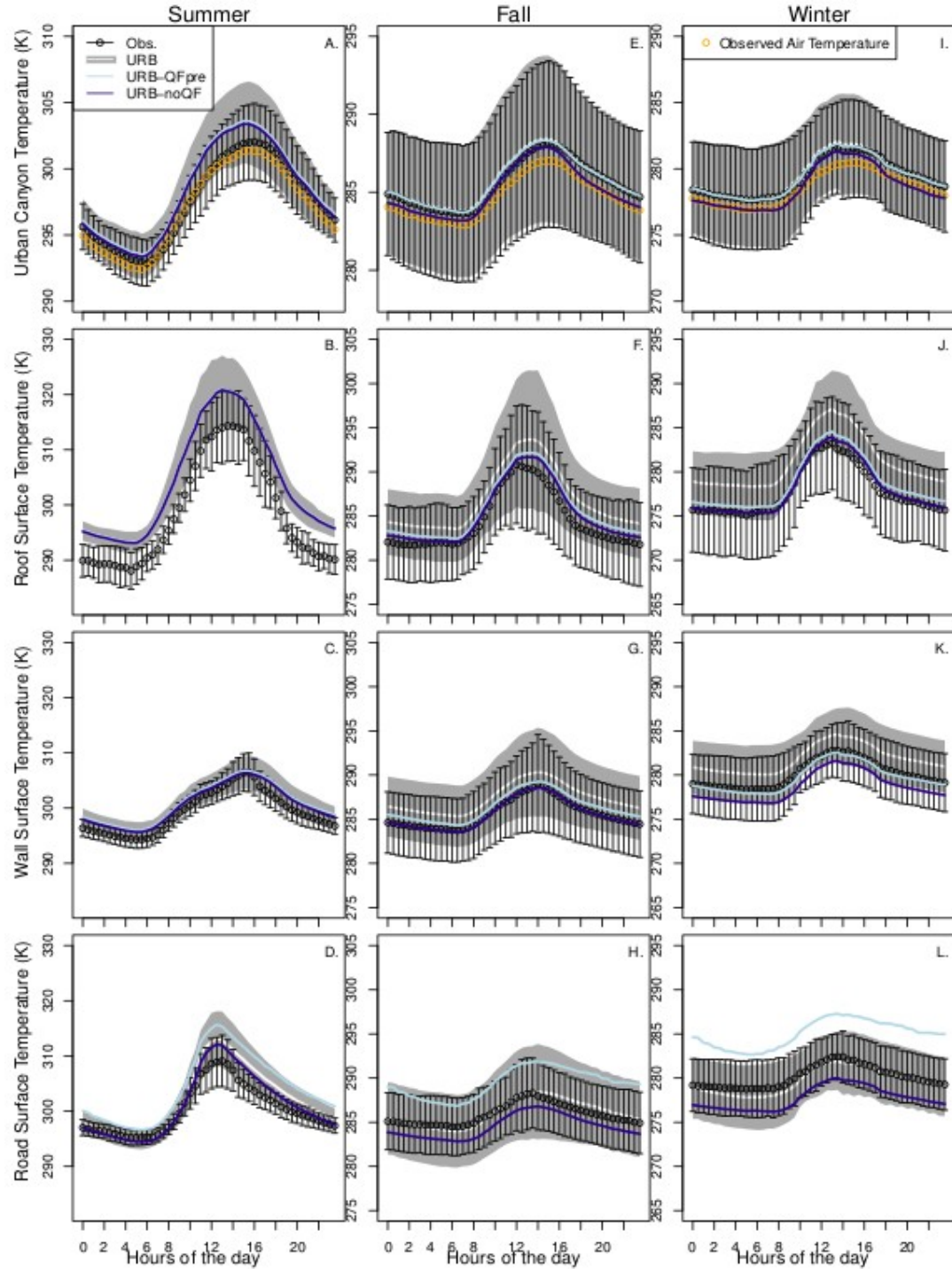| Experiment	$\Delta \mathrm{Qe}_{roof}$	$\Delta \mathrm{Qe}_{imprvrd}$	$\Delta \mathrm{Qe}_{prvrd}$
SOILTEX1	-	-	3.2
SOILTEX2	-	-	1.3
SOILTEX3	-	-	-2.2
SOILTEX4	-	-	-2.3
WPOND+50	1.3	0.5	-0.009
WPOND-50	-1.5	-0.6	0.01

Results for Toulouse
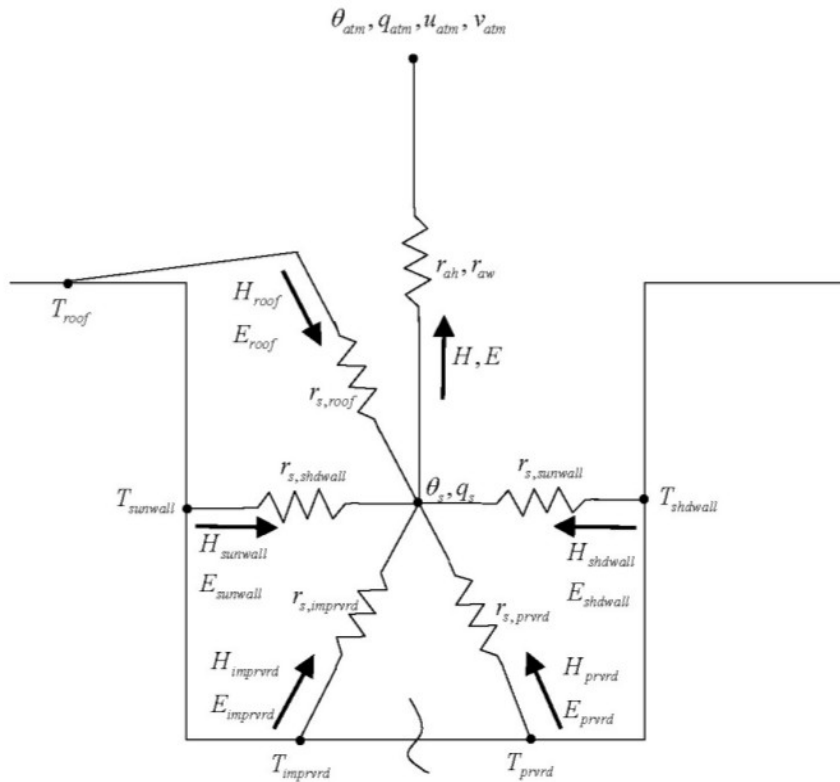
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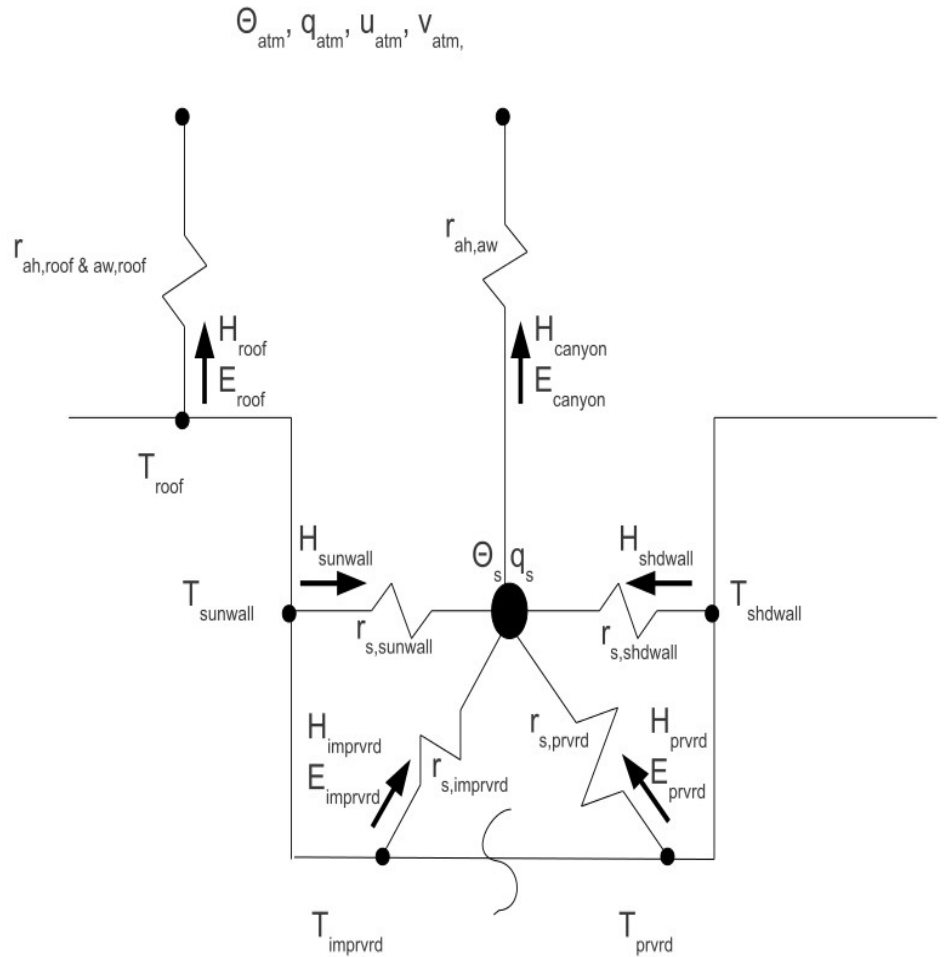
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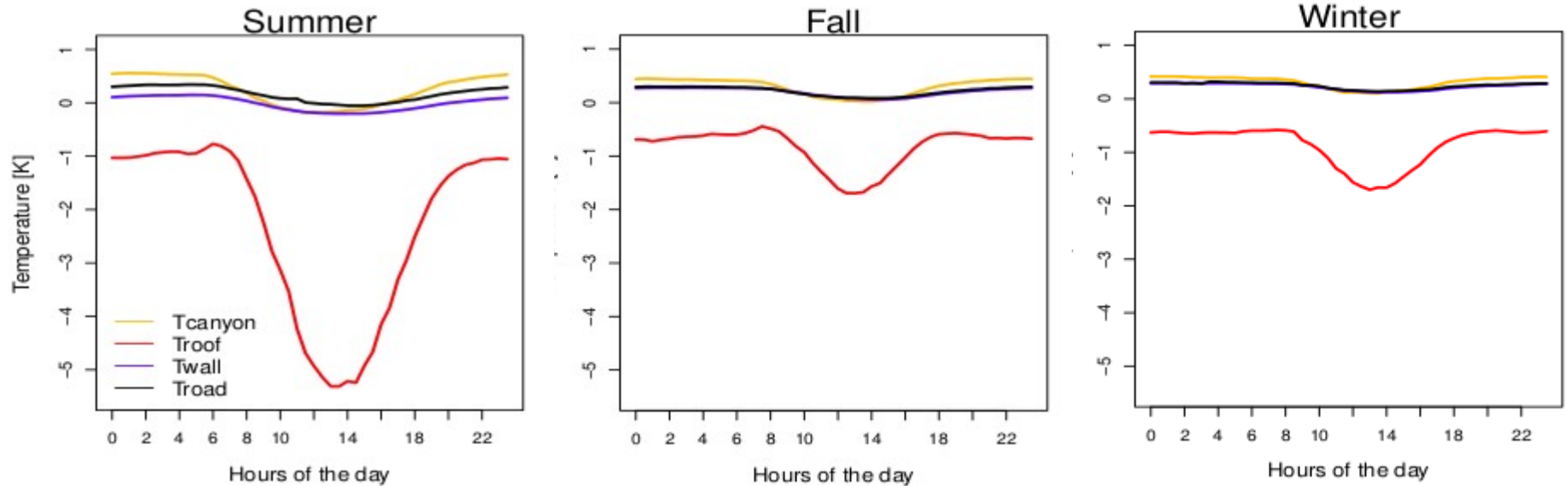
(de-) coupling of the roof

Original CLMU

Adjusted CLMU

(de-) coupling of the roof

Higher canyon air temperature
Sligthly higher wall and road temperatures

Similar canyon air temperature
Similar higher wall and road temperatures
Strong cooling of roof surface tempatures

Conclusions

▪ In general, CLMU is able to simulate the urban surface energy balance, with a better performance for Toulouse compared to the Melbourne sites.

▪ The pervious fraction is able to mimic "vegetation" in the canyon, although e.g. shading of trees is not yet present

▪ The present anthropogenic heat parameterization is too dynamic.

▪ As the roof fraction in urban areas can be rather large, the treatment and coupling of the roof to the air aloft / urban canyon properties is important

▪ Intuitively these results suggest that the choice of "model complexity" relates to the "site complexity".

Thank you!